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Assessing climate change vulnerability and local adaptation strategies in adjacent communities of the Kribi-Campo coastal ecosystems, South Cameroon

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ABSTRACT

This study assesses vulnerability to climate change and local adaption strategies in the Kribi-Campo coastal area. Variables of exposure, sensitivity and adaptive capacity are described and assessed based on the community's perception and biophysical evidence. Historical changes in rainfall and temperature variables, mangrove cover and occurrence of extreme climatic events are taken as indicators of exposure. Losses of property and income structure are used as indicators of sensitivity. Human, natural, social, financial and physical assets are used as elements of adaptive capacity. Focus group discussions were held with key informants in 12 settlements, and a survey was conducted with 150 household representatives (14 Bagyeli pygmies and 136 Bantou) to gather perceptions on climate change and adaptation strategies. Results show evidence of increased -vulnerability due to decreasing rainfall and irregular rainfall patterns, increasing occurrences of extreme climatic events and increased levels of coastal erosion. These have resulted in several effects, most significantly in the decline of agricultural production, reported by 57% of respondents, and damages to housing reported by 30% of respondents. Adaptive capacities are low. > 60% of respondents do not use any adaptation strategy. All sectors considered, the identified responses to climate related phenomena include early harvesting of crop, farm abandonment, change of productive activity, change of farm location, house reinforcement. The study concludes that households living here are susceptible to the possible impacts of climate change. Income diversification, mangrove afforestation and climate education should be considered as priorities for adaptation in this area.

1. Introduction

Global climate change will have serious impacts on social, economic and ecological systems and in coming decades the frequency and magnitude of extreme weather, as well as the sea level is likely to rise (IPCC, 2014). Coastal areas in particular are highly vulnerable to extreme climatic events, such as storms or flooding. In addition to climate-related threats, increased population

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pressure and exploitation of coastal resources are currently transforming and degrading coastal lands, including economically and ecological important ecosystems. Mangrove forest, despite their values (sheltered nursery for a number of fish varieties, structural support for the coastline, protection against storm surge, etc.) have been degraded and destroyed because of indiscriminate human exploitation (Oyebade et al., 2010). Between 1980 and 2009, an increasing frequency of tropical storms have killed over 400,000 people and affected over 466 million more globally; but it is unlikely that the total impacts of these can be accurately measured due to (a) the paucity of publicly available data and (b) the discrepancies in reporting (Doocy et al., 2013). The impacts of climate change on rural coastal populations are compounded by the anthropogenic degradation of the coastal environment, and this cycle heightens the vulnerability of these populations to climate change.

Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. It is “the degree to which a system is susceptible to or unable to cope with adverse effects of climate change, including climate variability and extremes” (IPCC, 2014). The United Nations Framework Convention on Climate Change (UNFCCC) has called on all parties to formulate and implement programs to facilitate adaptation to climate change, and the methods for vulnerability assessment have developed throughout recent decades. Based on the Intergovernmental Panel on Climate Change (IPCC) guidelines, researchers have developed several assessment frameworks:

- Turner et al. (2003) and Locatelli et al. (2008) proposed a multidimensional framework for exploring the vulnerability of socio-ecological systems as a function of exposure, sensitivity and adaptive capacity
- Wongbusarakum and Loper (2011) proposed a set of 10 indicators to assess social vulnerability to climate change including: (i) demographically vulnerable groups, (ii) dependence on vulnerable resources and services, (iii) current household livelihood and income diversity, (iv) perceived alternative and supplementary livelihoods, (v) awareness of household's vulnerability to climate hazards, (vi) access to and use of climate-related knowledge, (vii) formal and informal networks supporting climate hazard reduction and adaptation, (viii) ability of a community to reorganize, (ix) governance and leadership and (x) equitable access to resources
- The Magnan (2009) framework for assessing adaptive capacity defined 6 influential factors including spatial configuration, environmental sensitivity, social cohesion, economic diversification, political-institutional structuring and living conditions
- Dolan and Walker (2004) identified broader determinants of adaptive capacity: access and distribution of resources, technology, information and wealth; risk perceptions; social capital and community structure, institutional frameworks that address climate change hazards.

These approaches provide a core set of best practices for use in studies of climate change vulnerability and adaptation; and an array of variables to measure the main components of vulnerability: exposure, sensitivity and adaptive capacity. Exposure is “the nature and degree to which a system is exposed to significant climatic variations” (Folland et al., 2001). Sensitivity is “the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli” (Folland et al., 2001; Gallopin, 2003). Adaptive capacity is “the ability of a system to adjust to climate change (including climate variability and extremes), to take advantage of opportunities or to cope with the consequences” (Folland et al., 2001).

Some attempts have been made to understand the impact of climate change and adaptation strategies in coastal areas of Cameroon. Molua (2009) identified mud slides, high tides, storm surges, salt water intrusion, flash floods, rain storms, landslides and lava flow from eruption as natural hazards experienced in the south western coast of Cameroon, which have caused houses flooded, houses collapsed, class rooms damaged, agricultural land flooded, cars destroyed, loss of lives, injuries as a result of flooding in the municipality of Limbé in 2001; maize field crops damaged as a result of wind storms along the Southwestern coast during the years 2000, 2003 and 2007; houses and banana fields damaged and loss of household appliances reported as a consequence of mudslides in Limbe and Isokolo in 1998, 2001 and 2003. Investigating the extent of vulnerability to coastal flooding in South-West and Littoral Regions of Cameroon, Munji et al. (2013) reported that flood-triggered migration has been responsible for the relocation of settlements some 3.5 km inland over the past 45 years, with a corresponding loss of about 989 ha of mangrove forest cover. House damage, loss of farmland, domestic animal loss, agricultural crop loss, and landscape deformation were further effects on settlement. Ellison and Zouh (2012) showed that the Douala Estuary mangroves of Cameroon have overall resilience but noted some inherent vulnerability due to the low tidal range of the area.

These works are indicative of the extent of vulnerability of Cameroon's coasts to climate risks. However, the Kribi Campo area is undergoing more intensive urban and infrastructural development, and little knowledge is available concerning the vulnerability of this part of the coastal system. This study is designed to assess variables of exposure, sensitivity, adaptive capacity and vulnerability to climate risks, and local adaption strategies.

The work seeks to answer the following specific questions:

- How vulnerable are local communities to climate hazards and what are the underlying causes of vulnerability shaping these communities?
- How do they respond (with coping or adaptive strategies) to the perceived changes, and are these responses adequate and sufficient?

This study adds to the body of knowledge useful information for adaptation planning in this area.

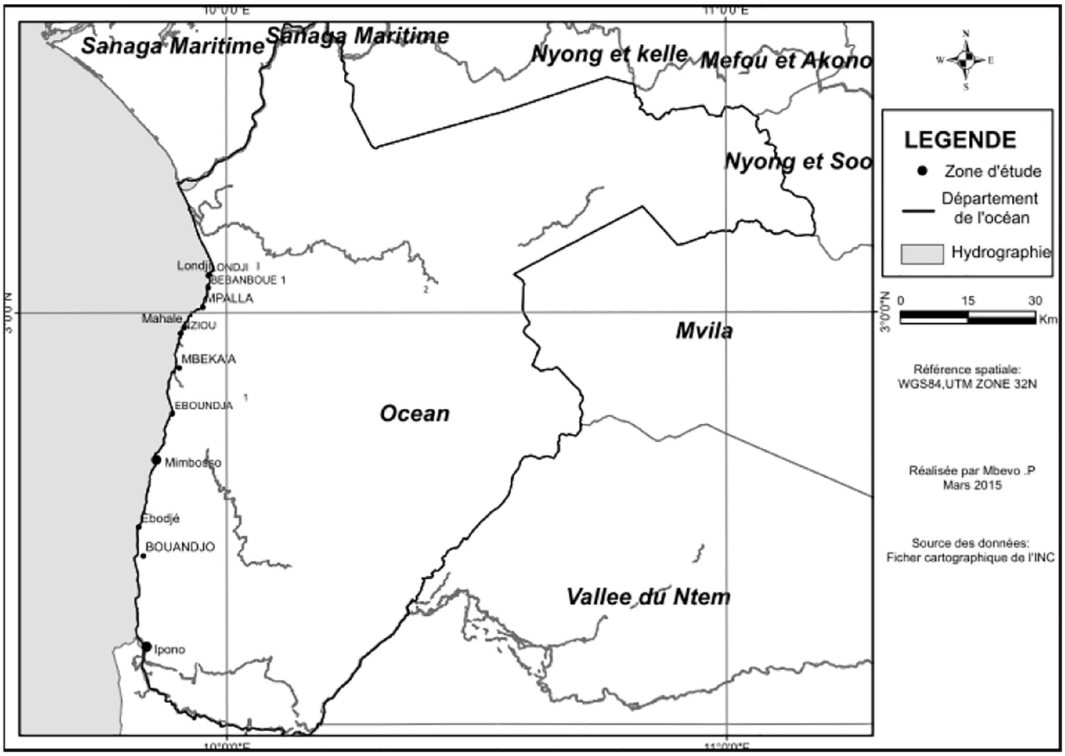

Fig. 1. Location of the study villages.

2. Study site

The study area is located in the Kribi-Campo coastal zone (Fig. 1). The landscape of the Kribi-Campo coastal zone is characterized by diverse habitats such as beaches, estuaries, lowland coastal Atlantic terra firm forests, mangroves, swamp forest (Tchouto, 2004). The study area is adjacent to the Campo Ma'an National Park area, an important biodiversity hotspot within the Guineo-Congolian Centre of Endemism (Tchouto, 2004). Its waters form the food basket of the region, supporting artisanal fisheries accounting for > 75% of landings in the region (Eyabi et al., 2001).

The climate of the Kribi Campo area is equatorial and exposed to oceanic influences, with two distinct dry seasons (November–March and July–mid-August) and two wet seasons (April–June and mid-August–October). Average annual rainfall generally decreases with increasing distance from the coast, ranging from 2950/mm/year in Kribi to 2800 mm in Campo. The more rainy months are from August to October (Fig. 2).The average annual temperature is about 25 °C.

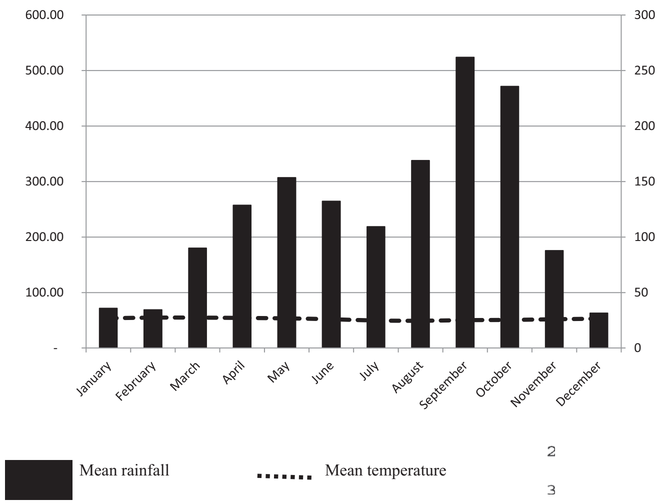

Fig. 2. Mean monthly temperature and rainfall diagram of the study area.

The hydrographical network is dense with small river draining basins with fast flowing streams and rivers in rocky beds containing many rapids and small waterfalls.

The main population groups in the study area are Bulu and Ntoumou (mainly farmers and hunters), Batanga, Yassa, Mvae and Fang (mainly fishermen, Mabéa (farmers, hunters, fishermen), and the Bagyéli (pygmies) traditionally hunter-gatherers but whose activity is progressively shifting to agriculture. The main crops are cassava mixed with banana and sweet potato. Yields are most often below the standards due to inappropriate agricultural resources and techniques (soil salinity, poor soil fertility and weed management, growing of mostly low-yielding traditional varieties, low use of agricultural inputs, etc.).

Generally, the area has a low population density of about 10 inhabitants per km^2 and is sparsely populated with most people living around Kribi, along the coast, and in agro-industrial and logging camps (ERE Développement, 2002). Maritime fishing is the main cash income generating activity.

> 80% of the population's settlements are located at most 1 km from the shoreline, and other than fishing, their livelihoods are primarily based on subsistence agriculture, sand excavation, non-timber forest product (NTFP) collection, hunting, tourism and employment in the region's industries (MINEP, 2011). The development of the Kribi deep water port and the Chad-Cameroon oil terminal, the expansion of rubber and oil palm plantations and the restrictions on the use of forest resources in the Campo Ma'an national park have threaten the already precarious traditional livelihoods of local populations. Moreover, sea level rise risk, changes in weather predictability, rainfall and temperature are considered to be among the most serious threats to sustainable development, with adverse impacts on the environment, human health, food security, economic activity and natural resources. The ability of local communities to remain resilient is rooted in understanding their current and future vulnerabilities.

3. Methodology and research methods

3.1. Vulnerability assessment framework

This study adopted the definition of vulnerability and its components of exposure, sensitivity and adaptive capacity as proposed by the IPCC. The definition of variables of exposure, sensitivity and adaptive capacity made use of the frameworks of Turner et al. (2003) and Locatelli et al. (2008); Wongbusarakum and Loper (2011); Magnan (2009) and Dolan and Walker (2004).

Historical changes in climate variables (rainfall, temperature), physical information (importance of mangrove cover, coastal elevation) and occurrence of extreme climatic events are taken as indicators of exposure. Previous mangrove mapping in the study area by Ajonina et al. (2014) and topographic data from Cameroon atlas were used for the mangrove mapping and elevation map preparation. Luni et al. (2012) hypothesized the following:

- the higher the rate of change of the climate variables and higher the frequency of natural disasters, the higher will be the exposure of the households to climate change and extremes;
- the lower the mangrove cover, the higher the vulnerability;
- the lower the elevation of a site, the higher the vulnerability;
- the more the household dependence on nature-based income, the higher the vulnerability.

Loss of assets (land, crop, equipment) due to climate related disasters over the last years represents the sensitivity for the purpose of this study. The analysis is based on the assumptions of Luni et al. (2012) that higher impacts of past climatic hazards will increase the sensitivity of the households to such events. The income structure will also determine the household sensitivity. A higher share of natural resource based income (composed of agriculture, fishery, forest, and handicrafts) will increase the sensitivity of the household as these sources are more dependent on climate.

Elements used to analyze adaptive capacity included human resource assets (highest education qualification in the family, trainings or vocational courses attended by family members, awareness about climate change), natural assets (land ownership), social assets (membership in community based organizations, access to credit, access to educational and sanitation facilities, development project), financial assets (livelihood diversification index) and physical assets (house quality, device to access climate-related information). Luni et al. (2012) assume the following the following: lower educational qualification, low amount of productive land and sanitation facilities, lower level of climate change awareness and diversification of income sources, poor house quality, poor social organization and access to climate related information are associated with low adaptive capacity and consequently, higher vulnerability.

There are various ways to classify and distinguish between adaptation strategies. The study adopted the framework of Klein and Nicholls (1998) to identify and classify the different adaptation options implemented in target communities.

3.2. Data collection procedure

Firstly a literature review was done based on reports, research papers, documents and other materials from various sources. A reconnaissance survey was conducted along the coast line from Lonji to Ipono to become familiar with the study area and 12 villages were selected at random for the study. The subsequent field study consisted of focus group discussions/community meetings and household interviews in the sampled settlements.

During the focus group discussions, the relative importance of mangrove and other land use type was evaluated using scoring techniques in participatory rural appraisal (Lynam et al., 2007).A total of 200 people participated in these focus groups, with an

Table 1
Number of individuals sampled per village.

Villages	Number of respondents		
	F	M	Total
Bibambwe		4	4
Bouandjo	4	11	15
Ebodje	5	10	15
Eboundja I	8	9	17
Ipono	10	5	15
londji 1	8	7	15
londji 2	5	6	11
Mahalé	4	1	5
Mbéka'a	4	6	10
Mimbosso	4	8	12
Mpalla	14	1	15
Nziou	5	11	16
Total	71	79	150

average of 20 per village. To avoid gender bias, they were men and women aged 25–65, experienced in fishing, hunting, farming and collecting. This relative importance was assessed by negotiation and informants were prompted to ensure that uses were not overlooked.

During these focus group discussions, information on perception of climate risks, effects on local communities, and their adaptive capacity were also captured.

Household surveys were conducted to gather information on socio-economic conditions, climatic phenomena, their effects on livelihoods and the adaptation practices to cope with them. In each village, a local assistant was used as translator. The survey was conducted by using questionnaire. A total of 150 respondents were interviewed in the 12 selected villages on the basis of a random sample (Table 1). Direct observation was carried out in the respondents' compound. Different adaptation strategies adopted by the people to cope with climate change were documented. These observations were utilized to triangulate the information gathered from the other sources.

Temperature and rainfall data needed for the research were collected at Kribi meteorological stations.

3.3. Data analysis

The rainfall and temperature data obtained were standardized and analyzed using the Ms-Excel in the form of rainfall and temperature curves. The trends of these variables, together with mangrove cover and household's income structure were used to developed exposure index.

Results from the household survey were used to develop the sensitivity and adaptive capacity indexes. Based on the assigned weights, simple average of all the scores was used to construct each index. Livelihood Diversification Index (LDI) was calculated; higher diversification indicating lower vulnerability and better ability of the household to switch among the activities when needed. This calculation is based on a modified Herfindahl index of diversification (Piya et al, 2012) calculated as follows:

$$\mathrm{Dk} = 1 - \sum_{i=1}^{n} (\mathrm{S_i})^2$$

where, D is the diversification index of village k, i is the specific livelihood activity, n is the total number of activities being considered, k is the particular village, and S_i is the share of i^{th} activity to the total household income for k^{th} village.

Weights were assigned to each of the variables of exposure, sensitivity and adaptive capacity based on a five categorized ranking system assigning scores of 1 to 5, 1 being the lowest and 5 the highest. Numerical values of these scores were determined using expert opinion and semi-quantitative methods. These values were further used to compute the Vulnerability (V) in the following equation of Gehendra (2012):

$$\mathrm{V} = \frac{\mathrm{E} \times \mathrm{S}}{\mathrm{AC}}$$

For the categorization of vulnerability, we used a four categorized ranking method as follow:

- Low = $V \leq 1$
- Medium = $1 < V \leq 2$
- High = $2\ V < 4$ and
- Very High ≥ 4

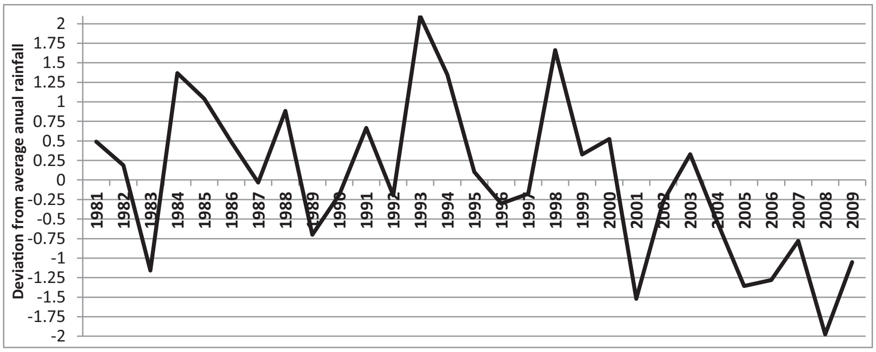

Fig. 3. Trends in average annual rainfall for the past recent decades.
(Data source: Kribi meteorogical station)

4. Results

4.1. Exposure

4.1.1. Temperature and rainfall trends

According to the country's climate profile, mean annual rainfall over Cameroon has decreased by around 2.9 mm per month (2.2%) per decade since 1960. Cameroon experienced particularly low rainfalls in 2003 and 2005. Projections of mean annual rainfall averaged over the country from different models indicate a wide range of changes in precipitation from − 2 to + 15% by the 2090s (McSweeney et al., 2010). Mean annual temperature has increased by 0.7 °C since 1960, an average rate of 0.15 °C per decade. It is projected to increase by 1.0 to 2.9 °C by the 2060s, and 1.5 to 4.7 °C by the 2090s.

In the study area, rainfall has been decreasing during the past decades. Annual rainfall averaged 2940.7 mm. The highest anomalies in rain fall were reported during the years 1983, 1984, 1993, 1998, 2001, 2005 and 2008 (Fig. 3). Annual temperature averaged 26.15 °C, though temperature data of the period 1981–1989 and 2005–2009 were missing. From 1990 to 2004, temperature values have been above the mean with very little variation (Fig. 4).

4.1.2. Coastal elevation

Elevation is a critical factor in determining vulnerability to inundation. We have collected elevation data on our research site and the following elevation map has been generated. It shows that most of the settlements, except in Ipono village are located in areas with an altitude ranging from 0 to 10 m (Fig. 5).

4.1.3. Mangrove cover

Mangroves have been seriously degraded in the study villages: 0.3 ha remaining in Mahalè, 30 in Ipono, 2 in Nziou, 3.5 in Londji, 1 and Londji 2 and Bibambwé, 6 in Ebunja 1, 2 in Mimbosso, 6 in Mpalla, 12 in Bouanjo and 3 in Ebodje.

During focus group discussions in the study villages, respondents declared that mangrove forests cover has remained constant in Ebodje and around Mimbosso villages. They were thus not as severely degraded as reported elsewhere. The mangrove areas are reported to be increasing in Bouanjo, Ebunja, Ipono, Mpalla and Nziou. Among these villages, Bouanjo and Ipono have been sites for a

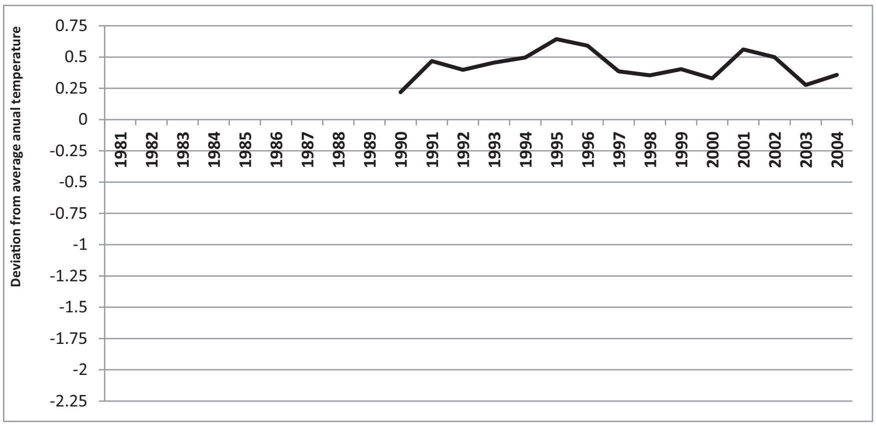

Fig. 4. Trends in average annual temperature for the past recent decades.
(Data source: Kribi meteorogical station)

Fig. 5. Elevation map of the study area.

mangrove reforestation project of the Ministry of environment, Protection of Nature and Sustainable Development but the project has delivered poor results because of inadequate follow-up. In Lonji1, Lonji2 and Mahalè, mangrove cover is reported to be decreasing because of human-driven unsustainable practices (wood cutting for fish drying in Lonji 2, and infrastructure development in Mahalè).

4.1.4. Occurrence of extreme climatic events

During the past decades, several climate extreme occurred in the area. These events have caused several effects including houses and classrooms damage, flooding of main high way from Kribi to Edea, mangrove degradation, destruction of fishing equipment and the falling down of many trees.

Some of the events like coastal erosion, strong waves and coastal storm surges are quite frequent in the area and do occur during periods of transition between the dry and the wet season.

4.2. Sensitivity

4.2.1. Importance of climate-related stressors

Based on community perception and evidence, different villages experience different level of risks. All respondents reported that rain storms occur in their village during the transition periods between rainy and dry season. They also mentioned flooding, salt water intrusion, coastal erosion, drought, changes in seasons. Rain storms was the most cited risk experienced by respondents, while changes in seasons was the least cited (Table 2). The villages Ebunja I, Mimbosso, Mpalla and Nziou recorded the highest number of threats reported.

However, though some of the respondents in study villages say they are worried about these threats, they often do not clearly relate those phenomena to climate. Coastal storms and severe flooding for example is perceived as a consequence of the anger of the gods of the sea.

4.2.2. Household income structure

Results from the surveys revealed a high share of fishing and agriculture in household income.

Though the households' income structure varied across villages (Table 3), there is high dependence of households on natural resources based income (68.22% of household income), what increases their vulnerability. Non-natural resource based income

Table 2
Number of households reporting climate related threats.

Settlements	Number of household interviewed	Number of household reporting climate related stressors					
		Changes in seasons	Coastal erosion	Drought	Flooding	Rain storm	Salt water intrusion
Bibambwe	4	1	1	1	5	5	1
Bouanjo	15	1	1	1	2	2	1
Ebodje	15	1	1	1	2	1	1
Ebunja I	17	15	12	14	11	14	14
Ipono	15	1	1	1	1	2	5
londji 1	15	1	2	1	5	5	2
Londji 2	11	1	2	1	4	5	1
Mahalé	5	1	1	1	4	2	2
Mbéka'a	10	2	1	1	2	3	4
Mimbosso	12	5	6	8	0	10	3
Mpalla	15	1	5	1	5	5	3
Nziou	16	1	2	3	4	5	3
Total	150	31	35	34	45	59	40

Table 3
Household's income distribution in each village.

Village	Natural resources based income (%)	Other sources of income (%)
Bouandjo	91.30	8.70
Mimbosso	84.62	15.38
Eboundja I	80.00	20.00
londji 1	69.23	30.77
Ebodje	66.67	33.33
Mahalé	66.67	33.33
Mbéka'a	66.67	33.33
Mpalla	65.38	34.62
londji 2	60.00	40.00
Ipono	58.33	41.67
Bibambwe	55.56	44.44
Nziou	54.17	45.83
Average	68.22	31.78

activities include commerce, tourism, and wage labors..

4.2.3. Relative importance of mangrove forests and other land use type

Based on community perception, six functional landscapes were identified: beach, freshwater including rivers and streams, sea, mangrove forest, non-mangrove forest and farm lands. The four most important landscapes for the provisioning of goods and services are forests, beach, farmlands and sea (Table 4). Rivers and mangroves were not given enough weight in the provisioning of goods and services. Informants assigned high scores for sea as a source of food and trade products (this comply with the reality of the area), for beach as a source of hobby and they consider farmlands and sea as more important for their future. The forest ecosystems are favored

Table 4
Relative importance of landscapes for the provision of goods and services.

Goods and services	Beach	Rivers	Sea	Mangrove	Forest	Farmlands	Total
Food	2,5	9,2	**32**	0,3	25	31	100
Traditional medicine	0	1	2	0	**94**	3	100
Light construction	0,5	0	0	1	**98,5**	0	100
Permanent construction	43	8	7	0	**42**	0	100
Canoe fixing	28,5	0	0,5	0	**71**	0	100
Tools	2,5	0	0	0	**91,5**	6	100
Fuel wood	2,3	0	0	1,5	**71,5**	24,7	100
weaving/fibres	5	0	0	0	**81**	14	100
Ornamental/tradition/rites	28,5	7,5	18	0	**39,5**	6,5	100
Trade products	2,3	6,2	**35**	2	25,5	29	100
Hunting	0	0	0	1	**77**	22	100
hobby/toys/pleasure	**69**	6	9,5	0,5	5	10	100
Future	9,5	3	34	0,8	17,7	**35**	100
Total	191,1	31,7	106	6,8	714,2	150,2	1200

Table 5
Proportion of respondent by educational level.

Settlements	Total number of respondents	Number of respondent by educational level			
		Illiterate	Primary school	High school	University
Bibambwe	4	0	2	2	0
Bouanjo	15	0	6	9	0
Ebodje	15	0	9	6	0
Eboundja I	17	4	9	4	0
Ipono	15	0	8	7	0
londji 1	15	1	9	4	1
londji 2	11	2	2	7	0
Mahalé	5	0	1	4	0
Mbéka'a	10	0	5	5	0
Mimbosso	12	11	1	0	0
Mpalla	15	1	6	8	0
Nziou	16	0	4	10	2
Total	150	19	62	66	3

for the provision of most goods and services (construction material, tools, rites, food including non timber forest products, fuel wood, bush meat,…).

One problem with this method is that scores may be inflated by past and potential uses not currently realized. This explains some apparent anomalies observed in the ranking of landscape, and the contradiction of local opinion which seems to regard forest as less important than sea. Although the sea provides the highest share of food and trade products, the forest landscapes as it appeared from this participatory scoring exercise, provide a diversity of products and services, greater than those provided by the sea. Mangrove forests are also seen as less important for the local people. This is because they have been severely degraded over time and because of sensitization campaigns recently conducted in the area that have significantly raise the awareness of local population on the need to protect these ecosystems. This might lead to higher perceived importance.

4.3. Adaptive capacity

4.3.1. Education of household

Most of the villages (8 out of 11) have education facilities and the average school attendance rate of children is above 80%. The educational status of the households has been explored through the survey (Table 5). It shows that multiple education status exist in the villages. It also shows that primary education has been completed by a large proportion of the interviewed people, a low percentage of households is illiterate. Furthermore, higher secondary school has been achieved by very high percent of members of these communities. However, the level of education of household members varies across villages. The highest educational level is found in Nziou village near Kribi city (probably because of proximity of schools) and the lowest in the Mimbosso village mainly inhabited by Bagyeli pygmies (Table 5).

4.3.2. Sanitation

Among the 10 villages, only 3 have health facilities. For their health care, local people rely on both the health centre and medicinal plants. Again lack of access to sanitation facilities and safe drinking water may contribute to the incidence of infectious diseases, especially during the wet season. It should be noted that because of salinization of the ground water, these communities rely on canal, river, open ponds and the collection of rain water which may seriously impact on the health of the villagers. The high prevalence of malaria and other water-borne diseases like typhoid and even cholera were reported by the majority of respondents.

4.3.3. Climate change awareness

The level of climate change awareness is still low among the communities. There is a poor access of household to climate information sources (Fig. 6). The very few information they obtain from locally operating NGOs, TV and radio broadcasting are limited to sensitization messages on the adverse impact of climate change, and rarely on weather information or adaptation/coping mechanisms.

4.3.4. Housing quality

Different type of houses exists in the study area: modern houses, semi-modern houses, houses made of wood, houses made of plant fibres and mud house or “poto poto”. House construction patterns show that 49.5% of local population has wood-made houses which indicate their poor social and economical status (Fig. 7). At the same time these house themselves are vulnerable and increase the communities risk during any climate hazards like floods or storms. Modern houses accounted for 29.6% of house types. Overall, the density of settlements is 7.9 houses per km of coastline.

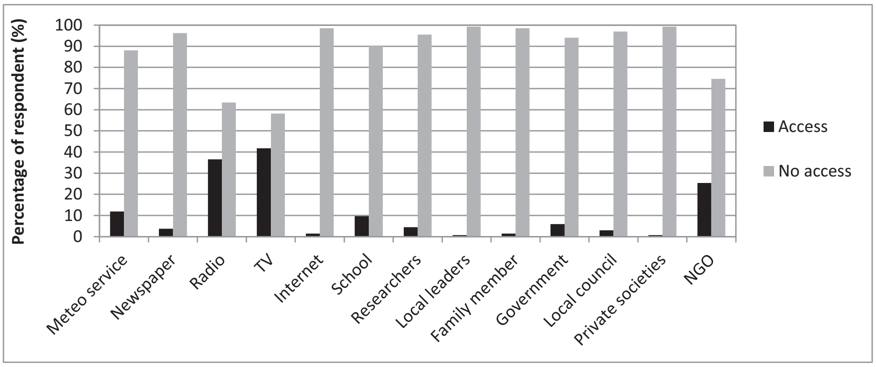

Fig. 6. Proportion of respondent with access to climate information sources.

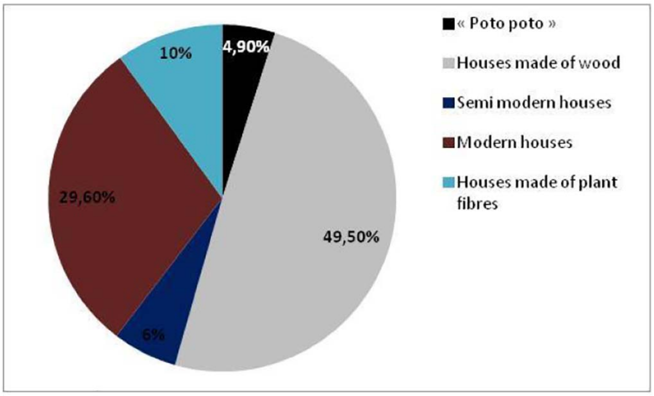

Fig. 7. Proportion of housing type.

4.3.5. Respondents' economic activities

The majority of the households depended on a single occupation as their main economic activity: 24 households (16%) for fishing, 21 household (14%) for farming, 14 (9.3%) for salaried work and 11 household (7.3%) for small commerce. Only 3 households (2%) depended on livestock alone and another 3 households (2%) on tourism.

A majority of 13.33% of household carried out both farming and fishing, 5% are occupied by farming and small commerce and

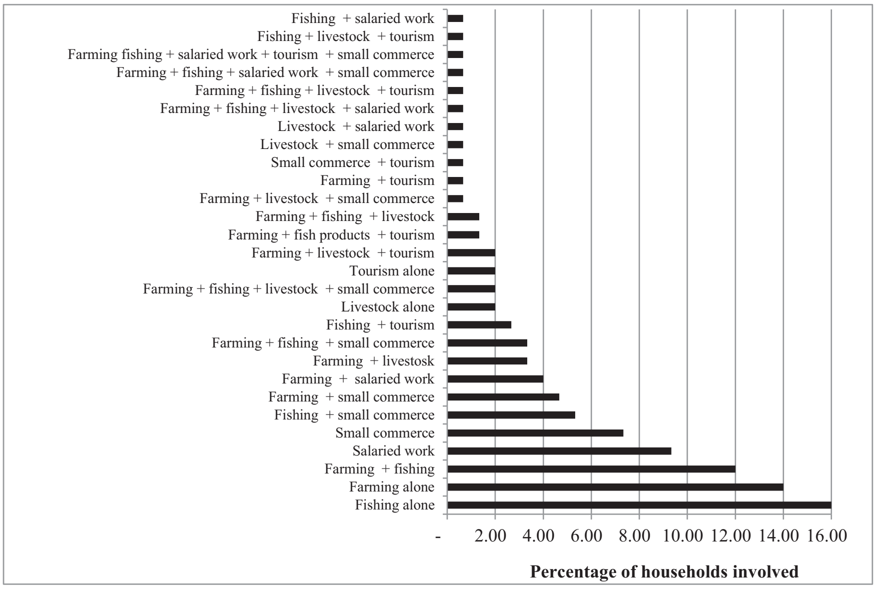

Fig. 8. Household livelihood diversification.

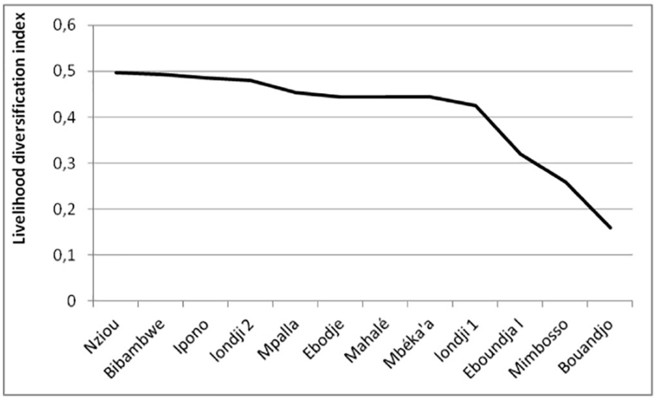

Fig. 9. Total household's livelihood diversification index of villages.

5.19% are involved in fishing and small commerce (Fig. 8).

Focus group discussions held in the villages established that by other business (besides fishing and farming), respondents in the study alternatively engage in various productive activities including salaried work, tourism business, livestock and small commerce.

The calculation of the livelihood diversification index for each village allows for some comparisons across settlements. The villages Nziou, Bibambwé, Ipono and Londji 2 have the highest index. Mimbosso and Bouandjo have the lowest index (Fig. 9).

4.3.6. Membership in CBOs

In this area, there is also a good network of community-based organizations. However, though the number of these groups is important, they suffer from lack of capacity and an effective and efficient functioning system to address climate related issues. The Ministry of environment, nature protection and sustainable development along with some NGOs (OPED, CARFAD) have organized awareness campaigns on mangroves in a few villages. These interventions were limited in time and without follow-up mechanisms, they have resulted in poor empowerment of local communities.

4.4. Vulnerability

Inter-village comparison of exposure index showed that Ebunja 1, Londji 2 and Mpalla villages are the most exposed to climate hazards. Factors of exposure varied across villages. The household income structure characterized by a high share of natural resource-based income, the poor mangrove cover and the low land elevation are the main factors explaining this high exposure index. Ipono village showed the lowest exposure index, determined by its high elevation and extensive mangrove cover.

In all villages, average sensitivity index was rated as medium. The agriculture and housing sectors are among the most affected by irregular rainfall, floods, storms, drought, and other extreme climatic events occurring in the area.

The adaptive capacity across villages is generally low, owing most to the poor social organization, poor awareness on climate change, low livelihood diversification and poor sanitation facilities.

The average index values for the ten study communities are presented in Table 6. The community with higher value of vulnerability index is more vulnerable. Mimbosso and Londji 1 are the most vulnerable villages while Nziou and Ipono are the least vulnerable. Bibambwé, Mahalè and Ebodje ranked third, fourth and fifth respectively, in term of vulnerability index score. Nziou village, despite having a comparatively high exposure index, fare better in terms of overall vulnerability due to its high adaptive capacity.

4.5. Local adaptation strategies

The International Panel on Climate Change (IPCC) defines climate adaptation as the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences. In the study area, the adaptation strategies used by villagers are more reactive than preventive (Table 7).

The great majority of respondents (64%) do not use any adaptation strategy. An assessment of these adaptation options by sector, based on field observations shows that they are ineffective and inadequate to address the stress faced.

5. Discussion

5.1. Vulnerability profile of the Kribi-Campo coastal area

Coastal communities in the Kribi-Campo coastal area are exposed to various types of climate hazards. Previous research findings in this coastal areas of Cameroon showed that most of the damage incurred by climate hazards that occurred in the past decades are climate, weather and water related (Molua and Lambi, 2007; Molua, 2008). According to the Cameroon's climate profile, since 1960,

Table 6
Exposure, sensitivity, adaptive capacity and vulnerability index scores of each village.

Variables	Bibambwe	Bouanjo	Ebodje	Ebunja I	Ipono	Londji 1	Londji 2	Mahalè	Mbeka'a	Mimbosso	Mpalla	Nziou
Rainfall abnormalities	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Temperature abnormality	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Coastal elevation	3.00	3.00	3.00	3.00	1.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Occurrence of extreme events	2.33	1.33	1.17	2.67	1.83	2.67	2.33	1.83	2.17	1.83	3.33	3.00
Mangrove cover	4.00	1.00	4.00	3.00	1.00	3.00	4.00	4.00	4.00	4.00	3.00	4.00
Average exposure index	2.86	2.06	2.63	2.73	1.76	2.73	2.87	2.77	2.83	2.77	2.87	3
Agriculture	2.33	1.33	2.00	2.33	2.00	2.33	1.33	2.00	2.00	1.00	1.67	2.00
Forest and forest resources	1.50	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Water resources	1.50	1.00	1.00	1.00	1.75	1.00	1.00	1.50	1.00	1.00	1.25	2.00
Beach	1.75	1.00	1.00	1.25	1.00	1.50	1.00	1.00	1.00	1.00	1.75	1.00
Fishery	2.00	2.00	2.00	1.33	1.00	2.00	2.00	1.33	1.00	1.00	1.67	1.00
Housing	2.00	1.75	1.75	1.00	1.75	1.75	2.00	1.75	1.75	2.75	1.75	1.50
Mangrove	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Income structure	2.00	5.00	3.00	4.00	2.00	3.00	3.00	3.00	3.00	4.00	3.00	2.00
Average sensitivity index	1.76	2.01	1.60	1.61	1.43	1.70	1.54	1.57	1.47	1.60	1.63	1.43
Education	2.00	2.00	2.00	2.00	2.00	1.00	2.00	2.00	3.00	1.00	2.00	4.00
Food sufficiency	2.00	2.00	2.00	2.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Sanitation	1.00	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00
Awareness on climate change	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
House quality	3.00	2.00	2.00	2.00	1.00	1.00	2.00	1.00	2.00	1.00	3.00	4.00
Membership in CBO	1.00	1.00	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00	2.00
Livelihood diversification	2.00	2.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	2.00	2.00
Average adaptive capacity index	1.71	1.57	1.43	1.57	1.43	1.43	1.57	1.43	1.71	1.14	1.71	2.43
Average vulnerability index	2.95	2.65	2.94	2.81	1.78	3.25	2.81	3.04	2.43	3.87	2.74	1.77
Vulnerability	High	High	High	High	Medium	High	High	High	High	High	High	Medium

Table 7
Classification of adaptation strategies and options in study area.

Climate change manifestation experienced	Livelihood assets most affected	Adaptation strategies and options		
		Protect	Accommodate	Retreat
Irregular rainfall/changes in seasons	Agricultural crop production	–	- Replace NTFP by some agricultural products - Buy alternative forest products in market - Resowing crop in case of damage	–
Sea level rise	Fishing	- Use of sand-filled bags - Mangrove reforestation	- Switch to other non-fishery activity (commerce, farming, prawn, etc) - Fishing in freshwater - Take care of fishing equipment	–
Flooding	Agricultural crop production		- Early harvesting - Farm abandonment - Change of crops - Resowing crop in case of damage - Change in cropping technique - Increase farms number - Use of chemical fertilizers	Change of farming area to use elevated lands Switching from farming to non-farm activities
	Housing	- Use of sand-filled bags - Mangrove reforestation	- Dig and increase water bed	Change of settlement
Rain storms	Housing	–	Reinforce roof protection Make new roof in case of damage	–
Coastal erosion	Housing	- Use of sand-filled bags - Mangrove reforestation	Build new house in case of damage	Change of settlement
Mud slide		–	–	Change of settlement
Drought		–	Make new roof in case of damage	–
Salt water intrusion		–	Use of sand-filled bags against flooding	–
Salt water corrosion		–	- Use of anti-roost ink - Change of roofs in case of damage	–
Raising temperature		–		–

mean annual rainfall over the country has decreased by around 2.9 mm (2.2%) per decade, and mean annual temperature has increased by 0.7 °C, an average rate of 0.15 °C per decade (McSweeney et al., 2010). In the Kribi-Campo area, the same decreasing pattern of rainfall was observed. Such a change validates that global warming can be revealed even at local scales. Fischer et al. (2002) reported that changes in rainfall amount and patterns, in addition to shifts in thermal regimes, influence local seasonal and annual water balances. These in turn affect the distribution of periods during which temperature and moisture conditions permit agricultural crop production. In addition, people who live in low elevation coastal zone that are < 10 m above sea have been described as at significant risk to the effects of sea-level rise (McGranahan et al., 2007). Our elevation map provides evidence of high exposure in the Kribi-Campo coastal area as all the settlements, except in Ipono area, are located at most 1 km from the shoreline with an altitude ranging from 0 to 10 m. In such context, mangrove forest would have been vital in protecting the settlements against shore erosion and storm surge. Unfortunately in this area has the most fragmented mangroves of the countries and these ecosystems have suffered severe degradation from urban and infrastructure development. A vulnerability assessment of mangrove forest in the Cameroon estuary by Ellison and Zouh (2012) showed good resilience of mangroves (5% reduction in area between 1975 and 2007 only) despite the predominance of the shrinkage of coastline. Unfortunately, our study area has only a few relics of discontinuous mangrove patches, what increases the exposure to flooding and sea level rise. A study by the Cameroon's ministry of environment in 2010 using a combination of expert opinion and climate models to assess the impacts of climate change on Cameroon estuary mangrove estimated the flood area at 49.5 km^2 for a rise of sea level of 0.20 m, and 330 km^2 for a rise of 0.90 m, which would require the forced displacement of 57.8% fishermen in the area of mangroves (MINEP, 2010). In addition, mangrove plant species according to their characteristics will react differently to flooding. The same study estimated an increase in salinity (2100) up to 30%, causing changes in the size and zonation of mangrove trees, probably reducing areas of *Rhizophora racemosa* in favor of *Avicennia germinans*. Another factor shaping the exposure of local communities is occurrence of extreme events.

In Central Africa, > 80% of people are reported to live exclusively on agriculture, fisheries, livestock and harvesting activities that are highly dependent on climate (Bele et al., 2010). In our study area, communities' income structure is characterized by up to 68.22% of household income depending on natural resources based income. Income diversification is relatively low and respondents highly rely on natural resources which they use in many different ways - as food, wood for timber or fuel, medicinal plants for health care, materials for income generating activities, and for spiritual purposes. Due to the effects of climate change and even more through forest exploitation, large-scale plantation and infrastructure development, the availability and distribution of these resources will be directly affected. The villages Bouandjo, Mimbosso and Eboundja I are expected to be among the most vulnerable in view of the high share of natural resource based income. Among the assets examined in this study, the agriculture (reduced crop productivity), and housing (damages of roof and walls, house destruction) are the sectors that are the most affected. Detailed investigations will be necessary to assess the economic loss incurred by community members as a consequence of climate related disasters.

The adaptive capacity is relatively low and varied with villages. Medium capacity is reported in Nziou village, where level of education, house quality and the network of community-based organization have been reported to be the best in the area. Though considered as key component of adaptive capacity (Robards and Alessa, 2004; Tompkins and Adger, 2004), social networks in other community are quite poor.

The adaptation strategies are more reactive than preventive. Preventive options included the use of sand-filled bags as barriers against flooding and mangrove reforestation projects led by the Ministry in charge of environment and some local operating NGOs. The first option is neither efficient, nor sustainable to address the flood issue. The second though theoretically associated with ambitious objectives suffer from adequate monitoring. Successful examples of mangrove restoration do not exist in the area.

5.2. Implications for adaptation planning

Experiences in other countries have shown that the ability to cope with increasing climatic hazards is highly dependent on the ability to diversify income sources (Adger, 2000; Barnett, 2001; Colding et al., 2003; Maripaz et al., 2013). Strengthening local communities and engaging them in alternative income generation activities will be of advantage in this area.

One of the most immediate and useful adaptation strategies should be to protect the mangrove forest from deforestation and implement a massive afforestation program all along the coastal belt. Mangrove planting and restoration are increasingly viewed as an entry point for synergies between mitigation and adaptation to climate change impacts because mangroves can both facilitate sedimentation and dampen wave stress (Wong, 2010). Afforestation will also help stabilize the land, create more accretion leading to more land, raise the level of topography that will reduce inundation by sea level rise and also increase carbon sequestration. Cropping practices may also be changed in the area. New varieties may be developed to withstand higher salinity and higher temperatures.

Our results also revealed the degree to which climate vulnerability is explained by the poor adaptive capacity of local communities. Striessnig et al. (2013) show that education is among the most important social and economic factor associated with a reduction in vulnerability to natural disasters. It is likely that over the next years, large amounts of money will be spent on adaptation programs through the Kyoto Protocol adaptation fund, national governments, or other donors. It may be better to enhance the human and social capital in this area through education and capacity building in order to empower the populations to better cope with climate change in a way that will be to their best long-term benefit.

Overall, adaptation strategies should not be regarded as separate, but as an integrated element of every relevant policy of development in the area.

6. Conclusion

Communities living in the Kribi Campo coastal area of Cameroon have suffered some extreme events for decades (coastal storms, mush slide, flooding coastal erosion), hindering their current livelihood options and socio-economic development. There is a difference in hazard exposure of households living in different topography and different livelihood practices.

Climate change may a serious threat for future development in this area and there is a need to protect the coastal ecosystems and proper utilization of coastal resources. To understand community's exposure to climate change, indicators such as coastal elevation, rainfall and temperature trends, occurrence of past climatic change and availability of mangrove cover clearly identified that the studied communities are susceptible for the possible impacts of climate change on top of their vulnerability for climate-related hazards.

Sensitivity was analyzed from various assets (agriculture, forest and forest resources, water resources, beach, fishery, housing and mangrove). It shows a high dependency of communities on natural resources as people have main occupation fishing and agriculture. In terms of sensitivity, coastal households in this area are also highly sensitive to climatic hazards.

We can conclude that households living here are vulnerable to climatic extreme events and climatic variability much because of their poor adaptive capacity. Household groups with livelihoods based to aquaculture and fishing and forestry are the most vulnerable to climatic hazards. Non-farming households are the least vulnerable group in this project site.

Preparedness and response to natural disasters also show serious obstacles, for example the low percentage of households owning devices to access climate information (radio, TV, etc) may represent a barrier to massive communication of preparedness and response actions to a particular natural disaster. Nevertheless the study approach followed in this research could be more reliable if more indicators were used to express exposure, sensitivity and adaptive capacity components.

The research findings contribute to a growing body of evidence about the vulnerability of coastal communities to climate change.

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